

It will, therefore, be obvious that any general rules for estimating the magnitude of the change of compressibility of a substance from observations on other substances should only be applied after careful consideration of the nature and structure of the substances involved. In particular, rules deduced for the rate of change of compressibility of holocrystalline materials should not in general be applied to glasses.

PALEONTOLOGY.—*New Carboniferous invertebrates*—III.<sup>1</sup> GEORGE H. GIRTY, U. S. Geological Survey.

*Schizophoria peculiaris* n. sp.

Figs. 1-4

Shell very small, broadly ovate in outline, varying in proportions but always wider than long, highly convex, coarsely striated.

The pedicle valve may be compared to a cone which is elliptical at the base, very depressed, very oblique, and considerably arched in the apical part. The hinge line is equal to about half the greatest width but when the valve is viewed from above it is mostly concealed by the projecting umbonal parts. The outline, due to these two factors, has an ovate shape but little interrupted by the cardinal angles, with well rounded and strongly divergent sides and a broad gently convex or sometimes faintly emarginate anterior margin. The cardinal area is high, but not so high as it is wide and it is neither strongly arched nor strongly inclined backward. The beak tapers rapidly to a point and is not greatly incurved. The convexity is high and regular, though chiefly localized in the posterior part and the median line may be depressed into an obscure sinus.

The brachial valve differs in shape but little from the pedicle valve. The cardinal area is lower and it lies essentially in the plane of the shell margins. Though lower than the cardinal area of the pedicle valve, it extends almost as far beyond the hinge line and is relatively high for a shell of this kind and size. The beak (compared with the ventral beak) is blunter and more incurved. A median sinus is of more common occurrence in this valve than in the other, and though never strong, it is likewise more distinct. If a sinus is present, and especially if a sinus is also present in the pedicle valve, the outline in front is correspondingly emarginate.

The surface is marked by radial lirae that are exceptionally strong and coarse for a shell of this size. They are separated by relatively wide interspaces, though many of the interspaces are partly occupied by interstitial lirae which subsequently become as large as the others. The lirae vary in size and spacing and the surface generally has an irregular appearance. To this appearance of irregularity the tendency of the larger lirae to end abruptly in a large pore or hollow spine contributes somewhat, and also the varices of growth that some specimens developed. Hollow, prominent and interrupted lirae are not a conspicuous feature and on many specimens they are difficult to distinguish at all. They are mostly to be looked for on the pedicle valve. The varices of growth which are especially common and especially strong on these shells, of course interrupt all the lirae simultaneously.

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Most of the Schizophorias in our American Carboniferous faunas are large shells. The present species differs from them not only in size, but in other respects, so much that detailed comparisons seem unnecessary. That the shells included here merely represent the immature condition of some larger species seems unlikely, not only because they are associated with no large species of which on other grounds they could be the immature form, but because they occur in considerable numbers and are more or less uniform in size and in other characters. The largest specimen referred here has a width of 12 mm., the next largest, 10 mm. and so on down.

Horizon and locality: Upper part of the Hueco limestone; Marble Canyon, east face of the Diablo Plateau, Hudspeth County, Texas (station 6681).

*Pustula palmeri* n. sp.

Figs. 5-10.

Shell small, rarely 10 mm. in width, highly convex (in the pedicle valve), lacking both radial costae and concentric wrinkles that are either systematic or pronounced but marked by numerous small spines which project from large rounded bases.

Pedicle valve subquadrate in outline except for the projecting umbonal parts, the front and sides being more or less straightened merging in strong curves around the antero-lateral angles. The proportions vary in different specimens, but the width seems to be regularly greater than the length. The hinge line is about equal to the width below, but it is more apt to be slightly shorter than slightly longer. The shell is strongly and rather regularly arched. Transversely the curvature is somewhat subdued across the median part with a steep descent on either side to the small depressed auricles. The umbonal parts are rather prominent and they project considerably beyond the hinge when the valve is viewed from above but not more than is common.

The surface is primarily marked by spines which arise from large well defined nodes. The spines are numerous and though actually small, are rather large for the size of the shell. They are more or less regularly arranged on a plan which is fundamentally alternating or quincunxial. This arrangement, however, is not as a rule conspicuous, a formation in transverse rows being more obvious than any other. In some specimens curving oblique rows are formed at the sides and in others the development of spines and nodes is accompanied by a tendency to form large indistinct radial costae on the anterior parts. The nodes and spines become gradually smaller and more closely arranged toward the hinge line, near which all the transverse features converge to some extent. Several specimens have a row of small spines along the hinge margin, but this may not be a constant feature. On one of these especially the spines were developed in connection with a series of small, sharp, regular plications extending downward from the margin, a spine to each plication. The spines with their nodose bases are more numerous on some specimens than on others, and aside from number, the nodes vary also in size and prominence. On some specimens they are by no means conspicuous. The surface is marked by striae of growth in the nature of microscopic and irregular concentric wrinkles. Some of these are delicately lamellose. Though not developed regularly or at regular intervals, other striae much larger than the incremental ones occur here and there between the rows of

spines and pustules. More regularly large wrinkles or plications are developed near the hinge line but they lose their strength within a short distance except as they may be represented by the stronger grooves that pass between and emphasize the rows of spines.

The brachial valve corresponds in shape with the pedicle valve in the usual manner. It is strongly transverse and in outline rather subquadrate than semi-circular. It is gently concave so that a relatively ample cavity is left within. The curvature is not quite regular, being low over the visceral disk and more pronounced over the marginal parts without, however, any marked discrepancy.

The most conspicuous surface feature in this valve consists of small rounded indentations or dimples which evidently correspond individually to the nodes on the surface of the pedicle valve. These indentations become deeper and more elongate toward the cardinal margin, so that the elevations between them take the shape of more or less irregular wrinkles. Microscopic wrinkles of incremental nature cover the entire surface which sometimes also is marked by concentric undulations (broad grooves and narrow ridges), all very faint but fairly regular where they occur at all.

This valve also is armed with spines which are at least as numerous as the spines of the pedicle valve and much smaller. They occur distributed among the dimples and spring from the surface without giving rise to appreciable nodes.

Species of the general character of *P. palmeri* are rare in our Pennsylvanian faunas and I am able to name but two which can profitably be compared with it. *P. keytei* has fewer and smaller spines which were developed without appreciably disturbing the even curvature of the pedicle valve by giving rise to nodes or spine bases. Although the nodose or monticulate surface is not a constant feature in *P. palmeri*, at least in a conspicuous degree, it is a very common one. *P. keytei* is also somewhat smaller and it is somewhat differently proportioned, being comparatively long whereas *P. palmeri* is comparatively broad. *Pustula globosa* is more comparable to *P. palmeri* in size and shape but it has much fewer spines and the spines, though leaving large scars on the surface, did not produce distinct elevations in the nature of spine bases.

Horizon and locality: Cherokee shale; mine dumps near Joplin, Missouri.

#### *Pustula keytei* n. sp.

Figs. 11-14.

Shell very small, hemispherical, without radial costae, and without concentric plications, but covered with numerous small spines.

Pedicle valve irregularly ovate in outline with length and width about equal though commonly somewhat longer than wide. Outline in front of the hinge rather regularly rounded. Hinge a little shorter than the width in front, mostly concealed by the umbonal parts when the valve is viewed from above. Convexity high. Umbonal region rather gibbous descending abruptly to the small, ill-defined auricles and projecting well beyond the hinge. A section longitudinally would show the greatest height posterior to the mid-length with a gradually decreasing curve forward.



The surface, which is without even traces of radial costae, is marked by fine, incremental lines. The sides of the vault and the auricles show small subequal concentric plications most of which spread out and become indistinguishable over the intermediate parts. A few of the grooves may persist, marking off concentric bands but this is more or less sporadic and developed especially on the visceral disc. Some of the striae also are lamellose along the posterior side. The spines which are represented by scars or by fragments of the basal parts, were apparently small and perpendicular to the surface, from which they were developed without giving rise to conspicuous nodes or spine bases. They show a general tendency to form concentric rows and occur scatteringly over the median part of the vault but in more close arrangement on its sides.

The brachial valve is semicircular in outline. The width, though greater than the length, is by no means twice as great. The curvature is moderately strong but much lower than that of the pedicle valve so that a considerable space is left between them. The curvature is also fairly regular—perhaps a little strengthened over the marginal parts. The surface features are so subdued as to be rather inconspicuous. Very fine incremental striae can be seen and descending from the hinge fine obscure wrinkles which either lose themselves in passing across the intermediate part or give rise to faint concentric undulations. Scattered over the surface, though scarcely to be seen except in a favorable light, are small dimple-like depressions that correspond to spines on the pedicle valve and were apparently developed simultaneously with them. This valve also was provided with spines but in comparison with the spines of the pedicle valve, they are smaller and less numerous. Because they are small, however, some may have been overlooked and their number may really be greater than it appears.

Mr. Mather has described a species very similar to this from the Morrow group of Arkansas, of Pottsville age. I have a number of specimens from the Morrow that would naturally be referred under *P. globosa* and among them it is possible to find individuals that do not differ greatly from *P. keytei*, but most of the specimens and apparently the more typical ones, are relatively broader and were armed with distinctly larger spines. The spines are not only larger but apparently also less numerous on the sides of the vault and less closely arranged; the specimens from Arkansas, however, are not as favorably preserved as those from Colorado, and it has not been possible to compare them satisfactorily in a number of details. The superficial features of the brachial valve, for instance, are neither adequately described by Mather, nor are they in certain details adequately shown by my specimens. This valve is described as flattened over the visceral disk and abruptly deflected around its margins. Here again the two species appear to differ inasmuch as the brachial valve of *P. keytei* is regularly arched. It should be remarked, however, that some of my specimens of *P. globosa* (if correctly identified) are equally regular though others have a flattened visceral disc and a deflected margin as described. Another similar but less closely related form is *P. palmeri*. In *P. palmeri* the spines are more numerous and more

regularly arranged and they spring from relatively large, rounded nodes which, by reason of their regular arrangement, produce here and there the appearance of large, ill-developed radial costae.

Horizon and locality: Fountain formation (Glen Eyrie shale member); Glen Eyrie, El Paso County, Colorado (station 5100).

*Avonia williamsana* n. sp.

Figs. 15-19

Pedicle valve small, rarely more than 15 mm. in width. Width and length about equal, though the width is commonly somewhat the greater. Outline broadly subovate. Vault moderate in height, gradually enlarging, conspicuously ovate and without a sinus. Hinge line equal to the width in front. Auricles quadrate in outline, small, depressed, ill-defined.

Sculpture comprising growth lines, concentric striae, spines with their bases, and radial costae. The growth lines are fine and inconspicuous. The concentric striae may be fairly strong and numerous, or on the other hand, few and obscure. They are not restricted to the visceral disk but may occur at irregular intervals throughout the entire length of the valve. Not rarely they are so shaped as to make a step-like descent forward. Broadly speaking, the posterior half of the valve is marked by spiniferous nodes and the anterior half by spiniferous costae, but the one type of sculpture graduates into the other, and the change occurs at different stages of growth in different specimens. The umbonal region which is somewhat finely and irregularly corrugated, is marked by numerous nodes which are rather large and surmounted by spines which are rather small. In a general way the nodes occur in transverse rows and alternate in the rows. As growth proceeded the nodes became more elongated, passing into short costae that are interrupted by the transverse striae and these shortly became continuous costae that the weakened striae fail to disturb. The spines are numerous over all parts of the surface and produce nodes where they occur, but where the spines take off from continuous costae, the nodes do not conspicuously deform them. The transverse arrangement of the spines in rows in many places is very striking, but the rows are irregular, crooked, or discontinuous. The costae are strong and rather regular; about 7 or 8 occur in 5 millimeters.

The brachial valve is deeply semicircular in outline and considerably wider than long. In the form of an external mold it is moderately convex but it is decidedly less convex than the pedicle valve, especially over the umbonal parts. These are rather exceptionally prominent for a brachial valve, however, and indeed the curvature of the whole valve though varying in different specimens is exceptionally strong and rather regular.

The surface markings, still in terms of the external mold, are a close repetition of the surface markings of the pedicle valve. Small nodes cover the posterior part and pass by gradual elongation into continuous costae, also faintly nodose, the costae corresponding to the costae of the pedicle valve and the nodes to the spines upon them. This valve equally with the other, is equipped with numerous small spines, and here also the spines are conspicuously but irregularly alined in transverse rows. They occur in the grooves between the costae and the grooves are slightly depressed or enlarged where they occur. Of course the grooves represent costae on the shell itself and

the enlargements slight nodes at the bases of the spines. Returning to the valve in its condition of external mold, some specimens are crossed by delicate flat-lying but conspicuous lamellae spaced at fairly regular but remote intervals and marking stages of growth. Other specimens appear to lack the lamellose feature, and to present instead a surface marked by rather fine concentric wrinkles, which are obscure over the median region but gain in strength and regularity as they pass onto the sides of the vault and onto the auricles.

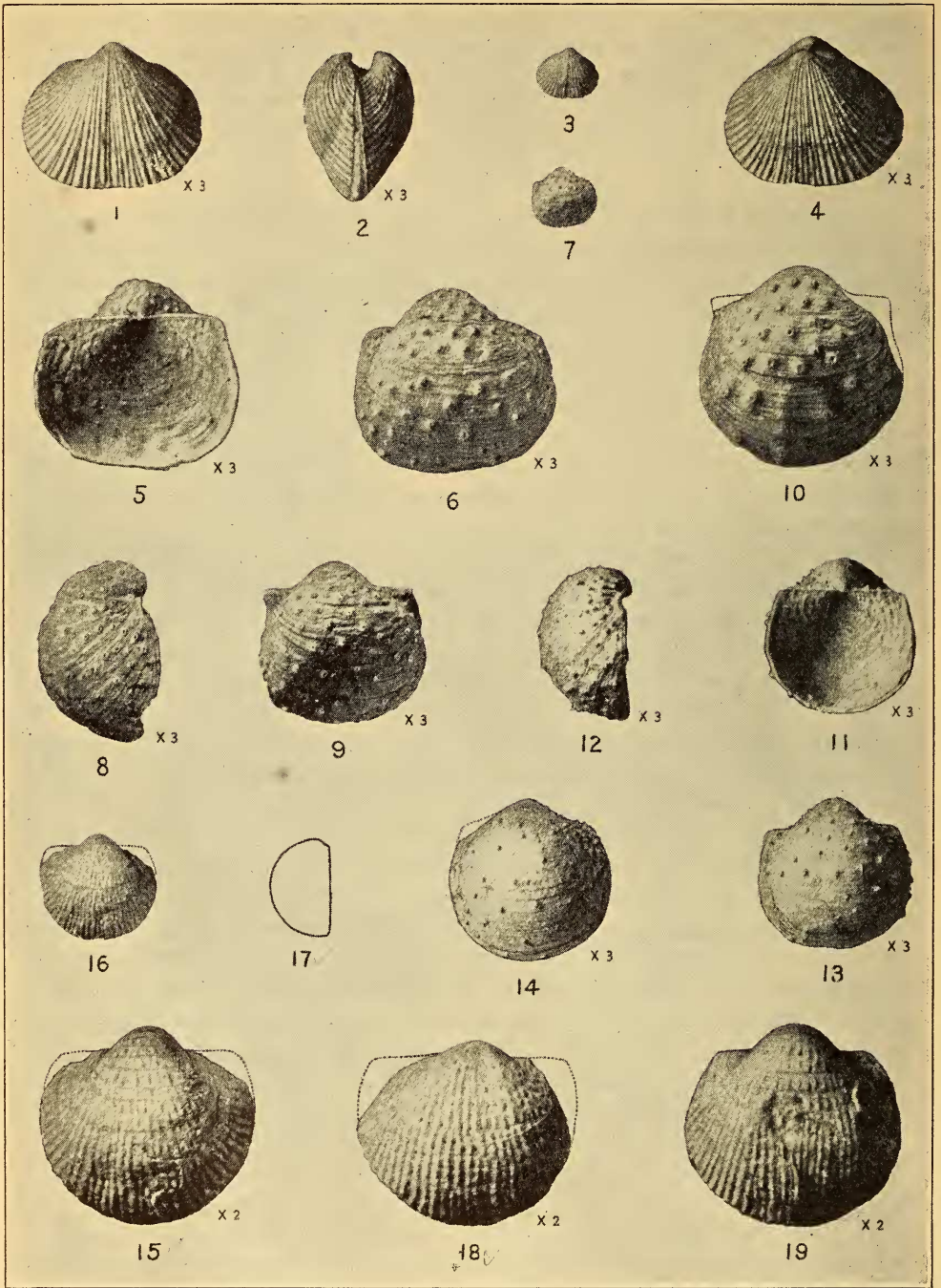
If *Avonia williamsana* is brought into comparison with other *Producti* at present known in our Mississippian faunas it is found to have many distinctive characters. It has much in common with some forms of *Productus arcuatus* to judge from Professor Weller's figures, but *P. arcuatus*, in its characteristic expression is a member of the *semireticulatus* group; the visceral disc in the pedicle valve is marked by concentric corrugations, the costae are coarser than those of *A. williamsana* and the spines fewer and much larger. Differences still more noteworthy are found in the brachial valve in which the visceral disk is well differentiated from the trail and strongly wrinkled, while spines, which are common on the brachial valve of *A. williamsana*, appear to be entirely wanting.

If that species were developed on a more generous scale, *A. williamsana* might be compared to the form that Professor Weller in his monograph figures from the Burlington limestone as *Productus* sp. (plate 14, figs. 26 and 27). Besides being much larger *A. williamsana* is distinguished among other differences by the more numerous spines and the more gradual appearance of the costae. The specimens used to represent the Burlington species in this comparison had their source in the white chert of Burlington age at Louisiana and Kinderhook, and without much question they represent the *Productus* sp. of Weller's monograph.

It is possible that instead of being described as new, *Avonia williamsana* should be identified with *A. pustulifera* Moore. The evidence on this head is somewhat contradictory. As represented by Moore's figures, *A. pustulifera* has a less spreading shape, coarser costae, and less numerous spines, so that *A. williamsana* appears to be something quite distinct. My collections from Osceola, however, contain a number of specimens which, on the one hand appear to be identical with *A. williamsana* but which I should be tempted to identify with *A. pustulifera* on the hypothesis that the original figures, even though they are photographic, do not fully or accurately portray the specific characters. My specimens, however, did not come from the same horizon as Doctor Moore's, a circumstance that may vitiate the fact that they came from the same locality. Moore did not describe the brachial valve of *A. pustulifera* so that the factors of identification are thereby much reduced.

Horizon and locality: Boone limestone (in beds of Keokuk age); Joplin, Missouri (station 1301A).





Figs. 1-19. For explanation, see page 397

## DESCRIPTION OF FIGURES

*Schizophoria peculiaris* n. sp.

Figs. 1-4. Different views of one of three cotypes. Fig. 3 is of the natural size; the others are enlarged to about 3 diameters. Hueco limestone; Marble Canyon, east face of Diablo Plateau, Hudspeth County, Texas, (Station 6681).

*Pustula palmeri* n. sp.

Figs. 5-10. Different views of 3 cotypes, figs. 5-8 representing one specimen, fig. 9 another, and fig. 10 a third. Fig. 7 is of the natural size; the others are enlarged to about 3 diameters. Cherokee shale; mine dumps near Joplin, Mo.

*Pustula keytei* n. sp.

Figs. 11-14. Different views of two cotypes, all  $\times 3$ . Figs. 11-13 represent one specimen, fig. 14 another. Glen Eyrie shale member of the Fountain formation; Glen Eyrie, El Paso County, Colorado.

*Avonia williamsana* n. sp.

Figs. 15-19. Different views of 3 out of 7 cotypes. Figs. 15-17 represent one specimen, fig. 15 being an enlargement to two diameters. Fig. 18 represents an external mold of a brachial valve  $\times 2$ . Some of the holes made by the small spines are here shown. Fig. 19 represents a pedicle valve,  $\times 2$ . This specimen like the original of fig. 15 is practically an internal mold. Cherty beds of the Boone limestone; Joplin, Mo., (Station 1301A).

ZOOLOGY.—*The copepod genera Broteas Lovén, Paradiaptomus Sars, Lovenula Schmeil, Metadiaptomus Methuen, and Adiaptomus Cooper.*<sup>1</sup> C. DWIGHT MARSH, Bureau of Animal Industry.

In connection with a study of *Diaptomus* it became necessary to determine somewhat clearly what species should be separated from *Diaptomus* and referred to the proposed genera *Broteas*, *Paradiaptomus*, *Lovenula*, *Metadiaptomus*, and *Adiaptomus*. It was found difficult to get from the authors who have used these names any method of determining by a few characters the generic limits of these proposed divisions of the Diaptomidae. Gurney, 1929, discussed the matter somewhat elaborately, but did not make clear a practical method of separating the genera. This led the writer to go over the literature to see if he could find out how the authors used these names and whether it might be possible, in some fairly simple way, to make diagnoses of the genera. This was necessarily nothing but a study of the literature, as no material of these forms was available for examination. Such a critical study is always difficult because many published descriptions are incomplete and there is always a possibility, especially in the examination of minute structures, that there may be mistakes of observation, in making sketches, or of interpretation. When there is a discrepancy between authors, it may be assumed that the later author is right, although, of course, this would not always be true.

In 1847 Lovén proposed the generic name *Broteas* for a South African copepod giving a somewhat elaborate description with figures. This

<sup>1</sup> Received August 3, 1931.